INDUSTRIALIZED BUILDING SYSTEMS CONSTRUCTION FOR THE KINGDOM OF SAUDI ARABIA

BY

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This thesis, written by **Try Puji Santoso** under the direction his thesis advisor and approved by his thesis committee, has been presented and accepted by the Dean of Graduate Studies, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN CONSTRUCTION ENGINEERING AND MANAGEMENT.**

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Dedication to Allah, Prophet Muhammad, and my beloved parents, sister, and brother.

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LIST OF ABBREVIATIONS

CIBD : Construction Industry Development Board

IBS : Industrialized Building System

KSA : Kingdom of Saudi Arabia

MMC : Modern Method of Construction

QDAS : Qualitative Data Analysis Software

ABSTRACT

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The construction industry in the Kingdom of Saudi Arabia (KSA) has experienced a significant increase in new projects in the past decades. Although the economy has been slowing down for the last couple of years, there are still significant needs in infrastructure and housing projects. Fulfilling those needs will be very difficult if the construction industry still uses the conventional construction method, where construction components are cast in situ. Industrialized Building System (IBS) was the approach that was taken by many countries that experienced similar problems. IBS concept can be defined as the implementation of manufacturing methods to construction-related activities in order to improve quality, reduce cost and shorten project duration. This study discusses the current practices, the barriers and the enablers for adopting IBS into the KSA construction industry. Interviews with the construction industry key stakeholders were conducted to assess the current practices of utilizing industrialized building system in the KSA, as well as to identify the barriers and the enablers for adopting such system. Furthermore, the identified barriers and enablers from interview result were verified by the survey questionnaire that spread among stakeholders in the KSA construction industry.

The study found that IBS has been adopted in the KSA construction industry to some extent. The adoption of such system for housing projects is limited to the non-volumetric pre-assembly in the structural concrete element and building facade area. Residential housing projects with repetitive design and having a substantial number of housing units perceive

the benefit of this system. Lack of awareness and knowledge on IBS, design inflexibility in the IBS, lack of government involvement, and conservative culture of using the conventional construction method are considered as the main barriers in adopting this system. While education, awareness campaign, and easily modify precast house system by giving design options to end users are considered the main enablers for adopting such system and to overcome the identified barriers.

The result of this study provides basis for future research to develop a framework in adopting industrialized building system in the Kingdom of Saudi Arabia.

ملخص الرسالة

الاسم الكامل: تري فوجي سانتوسو

عنوان الرسالة: إنشاء أنظمة البناء الصناعي للمملكة العربية السعودية

التخصص: هندسة البناء والإدارة

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شهدت صناعة البناء في المملكة العربية السعودية زيادة كبيرة في المشاريع الجديدة في العقود الماضية. على الرغم من تباطؤ الاقتصاد خلال العامين الماضيين ، لا تزال هناك احتياجات كبيرة في مشاريع البنية التحتية والإسكان. وسيكون تحقيق هذه الاحتياجات أمراً صعباً للغاية إذا كانت صناعة البناء والتشييد ما زالت تستخدم طريقة البناء التقليدية ، حيث يتم صب عناصر البناء في الموقع. كان نظام البناء الصناعي (IBS) هو النهج الذي اتخذته العديد من البلدان التي عانت من مشاكل مماثلة. يمكن تعريف مفهوم الـ IBS بأنه تنفيذ طرق التصنيع للأنشطة المتعلقة بالبناء من أجل تحسين الجودة وخفض التكلفة وتقصير مدة المشروع. تناقش الدراسة الممارسات الحالية ، المعوقات والعوامل المساعدة لتبني نظام IBS في صناعة البناء والتشييد في المملكة العربية السعودية. أجريت المقابلات مع أصحاب المصلحة الرئيسيين في صناعة التشييد من أجل تقييم الممارسات الحالية لاستخدام نظام البناء الصناعي في المملكة العربية السعودية ، وكذلك تحديد المعوقات والعوامل المساعدة لاعتماد هذا النظام. علاوة على ذلك ، تم التحقق من المعوقات والعوامل المساعدة التي تم تحديدها من المقابلة من خلال استبيان المسح الذي انتشر بين أصحاب المصلحة في صناعة البناء في المملكة العربية السعودية. وجدت الدراسة أن IBS قد تم تبنيه في صناعة البناء في المملكة العربية السعودية إلى حد ما. اعتماد هذا النظام لمشروعات الإسكان يقتصر على التجمع الأولي غير الحجمي في عنصر الخرسانة الهيكلية ومنطقة واجهة المبنى. يُتصور فعالية هذا النظام لمشروعات الإسكان ذات التصميم المتكرر لعدد كبير من الوحدات السكنية بدلاً من استخدام طريقة البناء التقليدية. يعتبر نقص الوعي والمعرفة حول IBS، عدم مرونة التصميم في IBS ، عدم مشاركة الحكومة والثقافة المحافظة مع الطريقة التقليدية بمثابة العائق الرئيسي أمام هذا النظام. بينما يعتبر التعليم وحملات التوعية وتعديل نظام المنازل الجاهزة بسهولة عن طريق إعطاء خيارات التصميم للمستخدم النهائي عوامل التمكين الرئيسية لتبني هذا النظام والتغلب على المعوقات المذكورة سلفا. تعتبر نتائج هذه الدراسة بمثابة دراسة أولية وأساس للبحث المستقبلي لتطوير نظام البناء الصناعي في المملكة العربية السعودية.

CHAPTER 1
INTRODUCTION

1.1 Research Background

World urban population growth has been reported to grow rapidly. 54% of the world's population resides in urban areas was recorded in 2014. This percentage is projected to expand to 66% by 2050 [1]. This expanding population leads to a rapid increase in demand for housing, which many countries could not meet. This condition leads to housing shortages. The housing shortage is not a new issue, as many countries have been facing this problem over the past few decades. Japan, for example, was struggling with housing shortage from the mid-1940s until the 1970s [2]. Sweden also faced low supply of housing during the 1960s [3]. Recently, Malaysia needed to develop 800,000 housing units in 1996 to meet the demand of housing for urban population expanding[4].

Besides the population growth, the rapidly expanding population in the Kingdom of Saudi Arabia (KSA) is also caused by large movements of migrants, with more than 100 thousand migrants per year of net inflow in 2010-2015 [5]. The urban population escalation in the KSA puts pressures on the shortage of housing and the existing infrastructure [6]. With average annual population growth 1.9%, by 2025 the population in Kingdom of Saudi Arabia is projected to expand from 31 million (2015) up to 37 million. According to the Ministry of Housing, Saudi Arabia needs to provide 3.3 million units to meet the demand in 2025, which is about 300,000 units per year [7]. In the past 40 years, using the conventional construction methods, the Saudi construction industry was only able to

provide 150,000 units per year [7]. To meet the demand gap for the housing shortage, an innovative approach to construction methods is needed.

Industrialized construction or building system as an approach to construction methods has been studied and implemented in some countries that experienced similar concerns [2, 4]. This system can be defined as the implementation of manufacturing methods to construction-related activities to improve quality while reducing project cost and duration [4], [8]–[10]. According to Jailon and Poon [11], compared to conventional construction method, prefabrication as industrialized construction methods has been proven to reduce construction labor on-site by 9.5%, construction project duration by 20%, and construction waste by 56%. It also improves the construction quality and durability as well as cost saving for both project owners and construction contractors. The research begins with a discussion on the concept of industrialized building system (IBS), which is then followed by the possibility of 'industrialization' of a building system in the KSA as a solution to the housing shortage.

1.2 Research Problem

Even though the KSA construction industry has been involved with techniques of Industrialized Building System as off-site construction, this approach commonly used in highway and bridge constructions for the past few decades. In building or housing project, Industrialized Building System is relatively new for the KSA construction industry [12]. Research is needed to investigate the industrialized building system implementation for KSA as a solution to improve productivity to meet the demand of housing.

The research questions that were addressed in this study are:

1. What are the current practices of utilizing an IBS in the KSA construction industry?
2. What are the barriers in developing an IBS in the KSA construction industry?
3. What are the enablers for developing an IBS in the KSA construction industry?

1.3 Research Aim and Objectives

This research aims to investigate the 'industrialization' of the building system in the Kingdom of Saudi Arabia as a solution to the housing shortage. The aim can be achieved by meeting the following objectives:

1. To study the current practices of utilizing an industrialized building system in the KSA construction industry.
2. To identify the barriers for developing an industrialized building system in the KSA.
3. To identify the enablers for the development of industrialized building system in the KSA

1.4 Research Scope

There were some limitations of this study:

1. The research focused on industrialized building system implementation in the residential building or housing type construction.
2. The data collection was conducted mostly in the Eastern Province.

The sample of this research included five main groups of the KSA construction industry stakeholders; there are owners or developers, consultants, contractors, and academics. Project owners or developers have an important role in making decisions to adopt the industrial building system or not. The government's role, with the authority that they have, is to set and implement regulations and policies that support the implementation of IBS. Project owners select consultants to assist them in converting their idea into project designs. In pre-design stage, consultants' team which include architects, engineers and planners will work to provide project designs, construction methods including project guidelines. They will then hand the designs to contractors as a constructor. In this stage, the other stakeholders who have important roles are manufacturers as the supplier of the construction components and fabricators. Beside the practitioners, academic point of view also has a key role in the adoption of IBS into the KSA construction industry. The results of this study provide the basis for developing a framework for implementing of industrialized building system into the KSA construction industry.

1.5 Thesis Contribution

The results of this study contribute in reducing the existing gap in knowledge due to the limited literature on the implementation of Industrialized Building System (IBS) in Kingdom of Saudi Arabia construction industry. The study also presents the barriers or challenges to the implementation of IBS and the enabling factors for adopting such system into the KSA construction industry.

1.6 Thesis Outline

This study begins with the literature review of Industrialized Building System (IBS) which presented in Chapter 2. This chapter provides the definition of IBS, including the benefits of the system, and followed by barriers and enablers in the implementation of this system. Chapter 3 describes the research design that needs to be followed to achieve the research aim. Chapter 4 explains details of the research findings and discussion on implementation of IBS in the Saudi Arabia construction industry. Finally, Chapter 5 concludes the thesis, along with suggestions for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides the current literature on Industrialized Building System (IBS). Section 2.2 presents a description of the literature on IBS. Section 2.3 described benefit the implementation of IBS. Section 2.4 discusses the implementation of IBS in the construction industry, including the lesson learn from another country which adopted the IBS as a solution to the housing shortage.

2.2 Description of Industrialized Building System (IBS)

Industrialized Building System (IBS) is an innovative approach to construction methods by implementing manufacturing methods in activities related to construction. This approach could improve project time and construction quality, as well as reduce construction cost and wastes. This approach is growing in the construction industry under the name of Modern Method of Construction (MMC) in the US; Off-Site construction in the UK, Australia and China; Pre-Fabrication in Singapore and Hong Kong, and Industrial Building System in Sweden, Japan, and Malaysia [1], [3], [8], [13]–[16]. The Malaysian Construction Industry Development Board CIBD [16] defines Industrialized Building System (IBS) as "*a construction technique in which components are manufactured in a*

controlled environment on-site or off-site, transported, positioned, and assembled into a structure with minimal additional site work.". Industrialized Building System starts in a factory as off-site production, which builds a prefabricated or precast component either in modules or units. It continues with to the delivery process from a factory to a construction site, and it ends with the installation of modules or units to complete building construction as shown in Fig 2.1 that adopted from the Offsite Management School [14, 17]

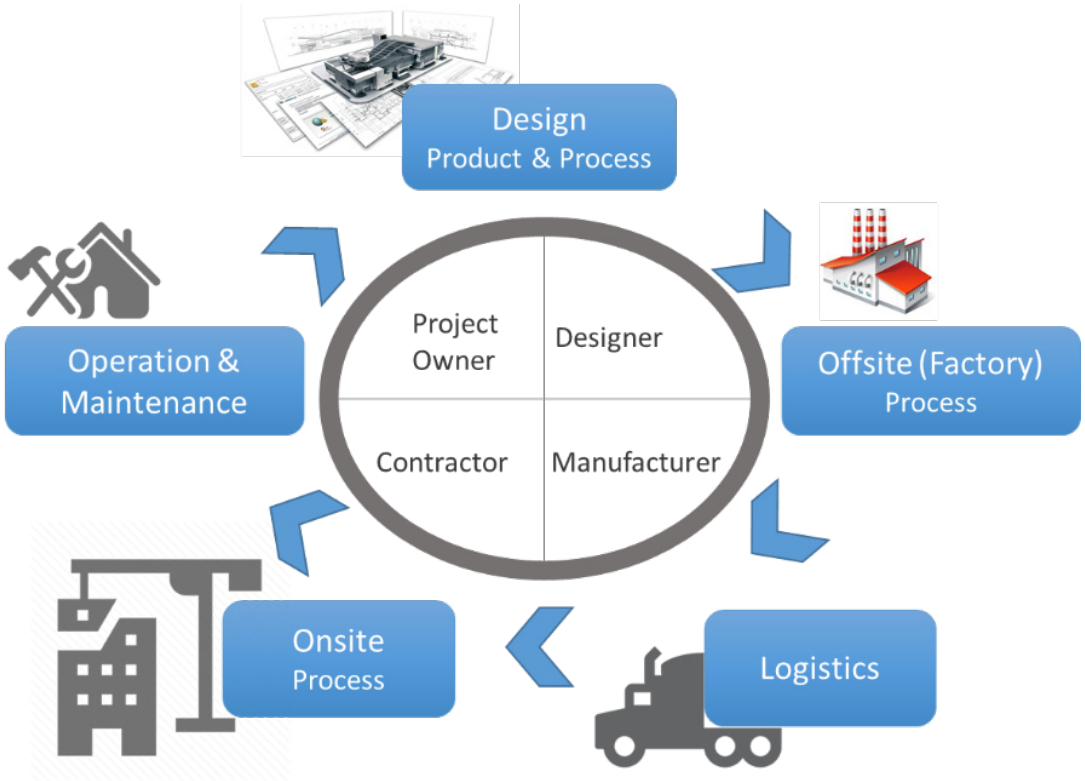

Figure 2.1 Industrialization flowchart [17]

Hairstans (2014) summaries the terminologies of this system as shown in table.2.1 below:

Table 2.1 Offsite Terminologies [19]

Term	Overview
Prefabricated construction	Cover off-site prefabrication of materials and parts, prefabrication of components and subassemblies, as well as volumetric units or modules.
Modular construction	the offsite process, performed in a factory setting, yielding three-dimensional modules that are transported and assembled at the buildings final location.
Industrialized Building Systems (IBS)	A construction industrialization concept in prefabrication construction with an additional emphasis on improved productivity, quality, and safety.
Open Building Manufacturing	The concept of applying production theory to construction employing standardized components that can be configured and assembled to provide a specific result.
Offsite Manufacture (OSM)	The manufacture and pre-assembly of construction components, elements or modules in a factory before installation into their final location

Historically, the development of IBS in standardization and pre-assembly started with the industrial revolution, as used by H.Manning in 1833 for the first prefabricated house in the Colonial Cottage for Emigrants. Then, in 1851, the Crystal Palace project in London by Joseph Paxton, who adopted the process of manufacturing in cast iron and glass, and set a modular design that could be preassembled off-site, continue with installation and set-up on site [9, 18]. Since then, the development of IBS was continued following the impact of the two world wars (1918 and 1945), where many countries, especially European countries (e.g., U.K, Germany, Netherland, Sweden) and also Japan, faced a problem of urgent needs for housing. To solve this problem, in the mid-1940s the government of Japan created a program to fulfill the need of 4.2 million housing units [2]. In more recent examples, Sweden needed to develop one million apartment units during 1965-1975 [3], and Malaysia needed to develop 800,000 housing units in 1996 to keep up with population explosion it

faced [4]. With the limitation of project schedule and project cost, including the need to meet the required project quality and quantity, Industrialized Building System was an effective alternative to conventional construction method.

2.3 Benefit the Implementation of IBS

Implementation of IBS as an alternative construction method contributes to positive changes to construction projects. Many types of research have been conducted that show project stakeholder who implements IBS as construction method gain benefits in terms of reduction in construction cost and time [4, 8, 9]; risk and safety [21]; improved work process in productivity to meet the required quality [3], [8]–[10]; and enhances sustainability of the project compared to conventional construction [10], [22]–[26].

Construction Global [27] identified the top six benefits of implementing IBS based on lessons learned from several companies in the United States and Australia that start construction process in a controlled factory environment;

1. Efficiency and predictability

   Standardization and repetitive work process in IBS optimized and simplified the work process, where each time the process is performed could improve the learning curve in factory activities [9], [27]. Off-site construction element designed with repetition process might contribute to simplifying the effective design process and higher productivity of designer [22], [28]. IBS also might improve predictability, as the impact of bringing building elements produced off-site where the working environment off-site is more controlled rather than on-site [19], [21], [29]. Jaillon

and Poon [11] studied projects in Hong Kong that optimized their construction process by adopting IBS, in terms of efficiency and predictability, demonstrated significant advantages in reducing construction time average up to 20%

2. Safety

   Performing construction activities off-site could eliminate safety risks regarding weather and visibility, as well as construction accidents (e.g., falling from heights and equipment accidents), as those activities are more controllable than the on-site construction [27], [30], [31]. The accident rate in a construction project which adopts IBS was, on average, 63% lower than conventional construction [25].

3. Sustainability

   Jaillon and Poon [25] stated that the implementation of IBS in Hong Kong was the major contribution to waste reduction and material conservation, with an average reduction of 56% compared to the conventional construction method. It also contributed to significant savings in costs [11]. Production of building element in factory directly tighter control the material usage and reduced waste output compared to the on-site activity [19], [31]

4. Less labor

   Producing building components manufactured under the IBS method could reduce the on-site labor requirement up to 43%. Reduced number of workers would lead to lower direct cost in terms of wages for the project as well as the company [27], [31], [32].

5. Less training

Compared to the conventional construction method, IBS which optimized work processes will create narrow activities of the worker. IBS puts the worker to a specific role in the production line, which leads to a simplified training program for improving worker's productivity, as well as reducing the cost of training or indirect cost of the project [21], [27].

6. No disruption to residents

   For construction projects in city center or near urban areas, IBS with off-site and prefabrication method provides social benefit of reducing pollution caused by a construction project such as dust and noise on site [25]. Moving construction activities, off-site creates a cleaner construction site as well as avoiding disruption to urban areas surrounding the project [27].

Although the benefits of implementing IBS have been recognized, many reports and researchers indicate that this system has not been widely used [14], [16]. According to the U.K. government figures that cited in the Building4change report [18], the recent implementation of off-site construction in the UK is reported only 7% of the total of construction output. In the US, as stated by Lu (2007) that cited by Rahman [16], the conventional construction approach still dominated the construction industry. The factory-built housings represent only 20% of the residential sector, while housing projects that were built using Modern Methods of Constructions (MMCs) were only 7%. The same condition also happens in China. According to Ge (2007), that cited by Mao et al. [15] stated that off-site construction is not widespread and has achieved limited progress.

2.4 Implementation of Industrial Building System

Some barriers have been identified and studied as reasons for low IBS implementation. Mao et al. [15] grouped those barriers into five clusters. They are industry structure and supply chain sector, a legal sector including policies and regulations, technological innovation, include cost, and market demand. Barriers to the low implementation of IBS include:

- Awareness and knowledge. The lack of awareness about the system create misinterpreted as high-risk process and not contributing to any benefit to project owner [12], [33]–[35],
- Lack of consciousness, results resistance to change from conventional method in the construction industry [14], [19], [34], [36],
- The usage of Design-bid-build project delivery system that separates design from construction. Involving the contractor and manufacturer after the design stage could increase the possibilities of design changes in the construction stage. The changing design has a huge impact on the increase of initial time and cost of the project [14], [33], [34], [37], [38],
- The focus on the lowest bid price, in particular in the public sector procurement [14], [29], [39],
- High initial cost and financial barriers for the stakeholders, because of the IBS required specialized equipment and skilled labor [31], [34], [40],
- Rigid and inflexible design, where limit design option. Including the lack of repetition possibilities, which is due to the client's bidding stage practices, hinders

standardization, consistently strive to improve the quality, and investments in both manufacturing and prefabrication facilities [14], [41],

- Technological dependency, which leads to a very low implementation level of industrialized building/ construction in developing countries [42],
- Manufacturing capacity in order to provide project needs [43],
- The understanding and misconceptions of the key stakeholders on the potential of industrialized building/construction [44],
- Shortage of skilled labor in implementing an industrialized building system (i.e., special erection procedure, use of new technology) [1], [3],
- Transportation restrain and process delivery issue [12], [31], [34], [41], [43],
- Inability to freeze the design in early stage and inability to make changes onsite [19], [41], [43], [45],
- Lack of guideline and information, where the process of the system completely different than conventional method thus the guidance required and flow information between design, production, and assembly requires more integrated [19].

The IBS with its benefits has been seen as a potential solution to the limitation of conventional construction method in the construction industry all around the world. Yet the adoption of the system has been limited. To overcome the barriers, there is enabler factor that identified to increase the uptake of IBS techniques by KSA construction industry:

- Conducting comprehensive awareness program and exhibition in order IBS well known and to be understood [31], [33], [43], [46]

- Provide comprehensive preliminary study in training, as well as skill training and courses for the university to set up a young engineer and designer with deep understanding about IBS [33], [41], [46]–[48]

- Establish R&D which focus on IBS, to be a room and forum for all stakeholders interact regarding IBS theme [31], [33], [41], [47]

- Improve Information Technology (IT) adoption, the use of updated IT tools to support integration in all activities in IBS process [33], [46]

- Improve the communication and collaboration of project owner, designer, contractor and manufacturer from the design and planning stage [41], [46]

- Government direct involvement in regulation, including Create standards and guideline for the design manufacture, and construction process [31], [34], [47]

- Design innovations, provide design option that allows to be easily modified and adapted in the future [35]

Implementation of IBS method in the Kingdom of Saudi Arabia (KSA) is driven by inefficiencies in project performance that leads to project delays that could increase the direct cost of the project [49]. According to Aburas [12], a workshop in Jeddah which organized on November 2010 was discussing and evaluating the implementation of IBS in the KSA. Construction project's stakeholders in KSA indicated that methodical of off-site

construction had been used for the past few decades in infrastructure and building projects. Even though they all agreed the IBS has benefits for shorter delivery time of project, increased quality, more controllable in health and safety, and have potential in cost saving; the forum found that the use of IBS has been only on non-volumetric, which is the use of off-site construction for only part of the building or structure (e.g., wall panel, half slab, precast column, and beam),. KSA's construction industry stakeholder mostly use off-site methods for a temporary structure, and the possibility was not seen in the usage of volumetric and modular construction in the main structure. This workshop [12] identified the barriers that construction industry stakeholders in KSA face in implementing the off-site method in volumetric and modular construction. The major barrier is the technical limitation. Compared to other countries, such as US or Japan which mainly use lighter material (i.e., wood), KSA's construction dominated by brick & concrete material. If off-site construction is applied, this will make the heavy panel and building element which will be difficult to transport & lift. Less of training and educational programs, negative state, and lack of infrastructure in order to support the transportation also considered as barriers to implement IBS in KSA. Despite these barriers, IBS or off-site methods was considered as an effective alternative to improving the construction industry's efficiencies. The forum suggested conducting the new training and educational programs for consultants (architects and designers) to change their approach, and consumer knowledge in IBS, including government legislation in boosting manufacturing in the construction industry.

Recently, precast concrete construction methods as one of the system in IBS has been used in the Eastern Province of the KSA for large construction projects, such as the expansion of Saudi Aramco camp in Dhahran with more than 1700 housing units, which is expected

to complete in 2018. Other examples include Al Rashed Residential towers in Khobar and the ongoing housing project by Saudi Basic Industries Corporation (SABIC) in Jubail Industrial City. Currently, precast concrete is mainly provided by three companies: Qandar Dywidag Precast Company, AlKifah Precast Company, and AlRashed Precast Company.

CHAPTER 3

METHODOLOGY

3.1 Introduction

As presented in the literature review chapter, industrialized building system is offering numerous benefits. Involving prefabricated building components, off-site casting and on-site installation in building system give a positive impact in improving productivity to meet required quality, as well as reducing working schedule and project cost. Industrialized building system was the approach that was implemented by many countries to reduce the gap and meet the housing demands. Currently, the Kingdom of Saudi Arabia is facing the same problem with housing shortage, and is still struggling in pushing the construction productivity, particularly in the resident or housing type of construction. Thus, this research aims to identify and assess the current practices, barriers, and enablers in the industrialized building system adoption in the Kingdom of Saudi Arabia.

This chapter discusses the research design that must be followed to achieve the research aim. It begins with the selection of research methods and followed by the scheme of this study, including the needed tasks in each research phase. Lastly, it presents the overview of qualitative analysis software with Nvivo that has been used for this study.

3.2 Research Methodology

To conduct a research, the philosophical foundation needs to be considered to find the appropriate strategy of inquiry, and the specific methods or procedures of research as a guideline to proceed the research. According to Creswell (2009), there are four philosophical worldviews, which are post-positivism, constructive, advocacy/participatory and pragmatism. This research closed to constructivism with the aim of studying complex human experiences, which gain knowledge through interaction with the wider human society and by looking into the complexity in participants' viewpoint on the research problem [50].

To achieve the study objectives in investigating and assess the current practice of IBS, a qualitative approach was chosen that underline the understanding and experiences, and followed by analyses of social and human problems. The instrument for data collection for this study is interviews with open-ended questions. The qualitative content analysis was then used in analyzing the collected data [51].

The phases and tasks for this study are shown in Figure 3.1.

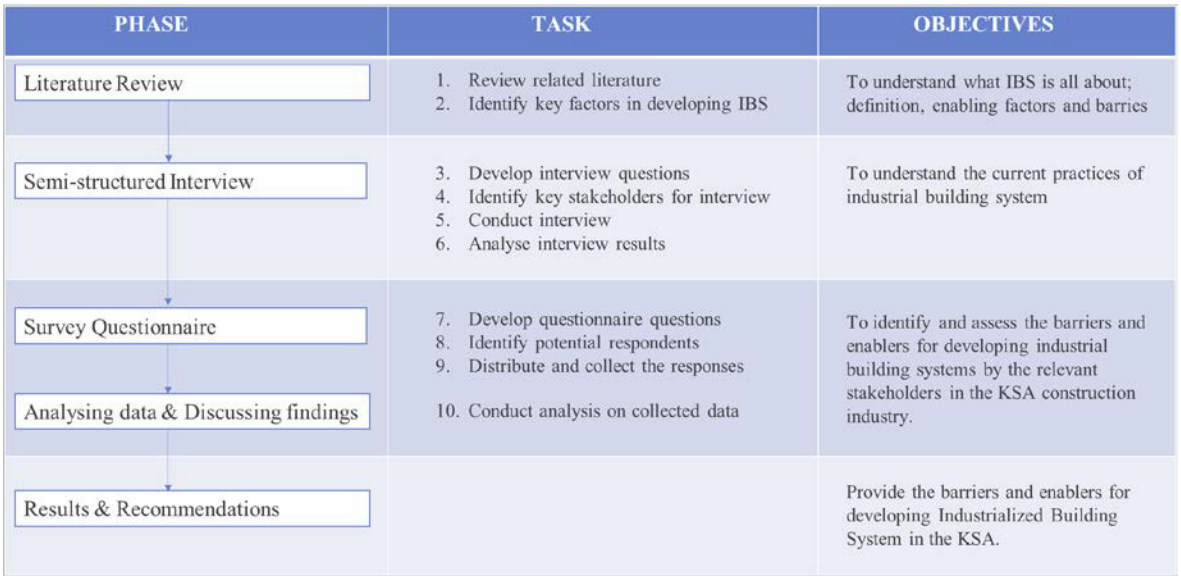

Figure 3.1 Scheme of study

The research methodology includes the following steps:

1. *The literature reviews on industrialized building or construction systems (IBS).*

The literature reviews provide understandings of the definitions and the concepts of industrialized building/construction systems (IBS); the factors that enable the successful implementation; and the barriers that have been experienced by the construction industry in other countries in adopting IBS.

2. *Semi-structured interviews to understand the current practices, barriers, and enabler on the implementation of IBS in the KSA construction industry.*

The interview questions were developed based on the literature reviews. The interviews were limited to companies that operate in the Eastern Province by exploring the views, experiences, beliefs and/or motivations of the respondents in adopting IBS.

In planning to conduct qualitative research with the interview as an instrument in collecting data, many qualitative researchers experts agreed that there is no solid

number of interviews needed to gather in advance [52]. Patria and Peter Adler, in Baker (2012) review paper, define the differences between quantitative methods and qualitative methods. The quantitative approach mainly focuses on describing and identifying 'what people do' using correlations, while the qualitative method uses subjective understanding in order to analyze on 'how and why people interpret, counter, act, and communicate' [52]. Qualitative researchers may not know how many data they need at the beginning of their research, which leads them to achieve their study aim with more open-ended, follow empirical finding, including the conceptual findings through the unexpected way. Reaching empirical saturation is the way to answer the number of data needed.

Guest et al. (2006) focused on the issue of saturation on their research to find the proper answer and estimate the sample size required to reach saturation. They found that saturation achieved when interviews number reached up to twelve (12) [53]. Patricia and Peter Adler, in Baker (2012) review paper, also suggested twelve (12) numbers of sample data for research which have limitation length of time. They categorized this as small size subject pool for research which has only one to two semesters for collecting data, doing analysis and write a paper [52]. This study has a similar limitation in term of length of time. Thus, this study targeted sample data up to fifteen (15) interviews.

The interviews were carried out following these steps:

- Prepare interview questions:

The questions were developed based on the previous research, which were captured from the literature reviews. The interviews were conducted using semi-structured

questions. Semi-structured interviews provide opportunities to explore responses further.

- Identify and approach potential respondents:

The respondents include building owners, engineering and design consultants, building contractors, precast companies, and relevant government departments. The respondents were limited to the companies that operate in the Eastern Province

- Conduct interviews:

The audio recording were used to capture the responses of the respondents. The interview divided into three (3) sections. The first section is demographic, the second section is about the current practices of IBS in the KSA as per interviewee experience and understanding, and the third section is about the barriers on the implementation of IBS and how the interviewee overcome the barriers.

- Analyze the interview results:

The audio recording of the interviews were transcribed. The transcriptions were then analyzed using qualitative analysis software, QSR International NVivo 10, to identify common, recurrent, or emergent themes related to the development of the industrialized building system

3. Questionnaire survey development based on the results of literature reviews and the interviews

A questionnaire survey conducted to verify the barriers and enablers for developing IBS in the KSA and were distributed via online to project owners, engineering and design consultants, building contractors, precast companies, and academician. In

addition to respondents in the Eastern Province, the questionnaire was also distributed to the respondents in other major cities, such as Riyadh and Jeddah.

4. Analyze collected data and discussing the findings.

The collected data were analyzed with qualitative content analysis. According to Flick (2009) [51], content analysis is used to analyze subjective viewpoints from collecting data with the interview. The procedure of content analysis used in this study is shown in general content analytic process model in figure.3.2

NVivo10 was utilized to analyze and identify the current practices, barriers, and enablers to the implementation IBS in the KSA construction industry. Statistical analysis using the value of mean, median and mode were used to analyzed survey questionnaire results in verifying the barriers and the enabler in implementing this system.

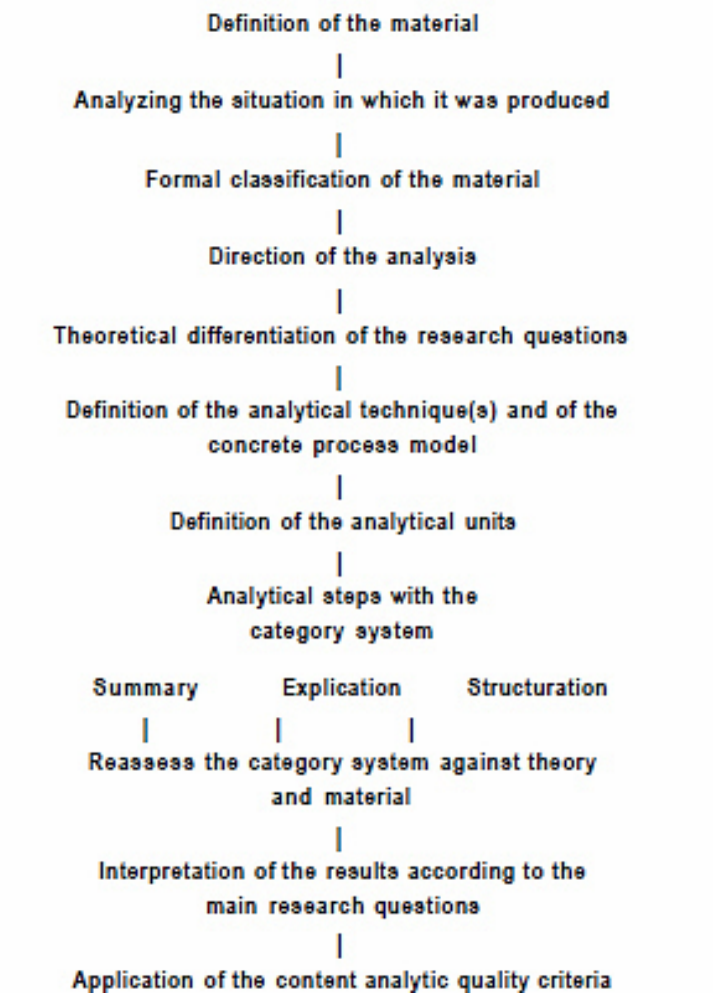

Figure 3.2 General Content Analytic Process Model [50]

5. *Provide recommendations.*

Based on the results of this study, some recommendations for future research are presented as consideration to the limitation of the study.

3.3 Overview of qualitative data analysis software (Nvivo)

As mentioned in the previous section, this study followed the constructivist paradigm, using qualitative approach to meet the objectives of the study. To help the study in analyzing the collected data, NVivo was selected as the qualitative data analysis software (QDAS). NVivo could help to organize and analyze the data effectively, where requires the researcher to code the data and to develop themes or categories. It can help researchers closer to the data and conduct in-depth systematic analysis that would be more difficult or even more to achieve manually.

There are five (5) features of NVivo in the analysis of qualitative data [54]:

- *Manage and organize data* – to organize and facilitates the analysis of data. It allows to classify, sort and arrange many types of non-numerical data such as interviews, questionnaires, focus groups or field observations, published research, images, diagrams, audio, video, web pages, other documentary sources [54], [55].
- *Manage and gather ideas* – provide easy access to conceptual and theoretical knowledge generated in the course of the study, including from supported data and help in examining the relationship between the data [54], [55].
- *Query and identify data* – able to ask simple or complex search of the data from the database. The results of queries were saved and allow for further analysis [54], [55].
- *Visualize data* – able to show the content and structure of ideas, themes, and the relationships with draw a model and chart [54].
- *Generate data report* – which contents of the qualitative database, the original data sources, the ideas and the conclusions [54].

This research limits the application of NVivo only for organizing data, managing ideas and identifying data, using the following processes:

1. Inputting sources (journal article, books and interview transcript)
2. Creating units of analysis or case nodes (participants)
3. Assigning attributes (demographics of participants)
4. Finding relationship and themes (coding into nodes, queries)
5. Using queries to find specific themes in data.

Data analysis process using NVivo in this study started with importing all formatted data into NVivo including interview transcript. All interview transcripts gathered into the Internals folder and grouped under a folder named Interviews. The imported interview transcripts have to consistently structured in paragraph styles. The auto-Coding feature was used to manage and create a node for each question and organize data into nodes. Further, the structure of nodes and sub-nodes, as well as unique codes were assigned to each question to avoid confusion between questions and answers. Common codes were grouped into three major themes corresponding to three main categories of current practices, barriers, and enablers. From the group categories, the relationships between the nodes were analyzed, and the study findings from the interview result were generated to answer the research questions.

3.4 Summary

This chapter discusses the approach and method used in this study. It began with philosophical assumptions which generate methods research approach that expected to achieve the objectives of the research, followed by the scheme of this study, including the needed tasks in each research phase. Next, present an overview of qualitative analysis software with Nvivo that has been used for this study. As mentioned in this chapter, a qualitative method is applied in this study to answer the research questions. The survey questionnaire is conducted to verify the interview result in barriers and enablers to the implementation of IBS in KSA construction industry.

CHAPTER 4

RESEARCH FINDING AND DISCUSSION

4.1 Introduction

As described in chapter 3, semi-structured interviews were conducted to collect information about the current practices, views, and experiences in the implementation of IBS and to identify the barriers and enablers for developing IBS in the KSA construction industry. An online questionnaire was conducted to support and verify the interview results. This chapter presents the findings and discussion of interview and questionnaire results.

4.2 Research Finding

4.2.1 Research Respondents

The interviews were conducted and recorded to gather the data in this study. The purpose of the interview is to explore the current practices of IBS implementation in the KSA construction study, especially in the housing projects. The interviews were conducted using open-ended questions to provide opportunities to explore responses further.

Thirteen (13), out of targeted 15, respondents were interviewed. They included two (2) building owners, two (2) engineering and design consultants, four (4) building contractors, three (3) precast companies, and two (2) academics. The interviewees represented different

stakeholders in the KSA construction industry to generate various opinions, perceptions, and to get wider point of views in the implementation of IBS. The list of the interviewees is shown in table 4.1. Instead of the interviewees' name, this study uses codes (e.g., I1, I2) to identify them.

Table 4.1 Respondent's Profile

Interviewee (I)	Position held	Discipline	Construction Experience
I1	Senior Structure Design	Contractor	5 - 10 Years
I2	Quality Control Manager	Manufacturer	> 10 Years
I3	Production Manager	Manufacturer	5 - 10 Years
I4	Site Engineer	Manufacturer	5 - 10 Years
I5	Construction Manager	Contractor	> 10 Years
I6	Planning Manager	Contractor	> 10 Years
I7	Project Engineer	Project Owner	5 - 10 Years
I8	Head of Projects Monitoring and Control Dept.	Project Owner	> 10 Years
I9	Managing Director	Engineering Consultant	> 10 Years
I10	Associate Professor	Academician	5 - 10 Years
I11	Deputy Executive Manager	Contractor	> 10 Years
I12	Assistant Professor	Academician	5 - 10 Years
I13	Co-founder & Lecturer	Engineering Consultant	> 10 Years

Furthermore, the selected interviewees should have at least five (5) years working experience in the KSA construction industry and have been implementing IBS in their projects. As shown in the chart in figure 4.1, from the thirteen (13) interviewees, six (6) of them (46%) have 5-10 years, and seven (7) (54%) have more than ten (10) years of experience in the KSA construction industry.

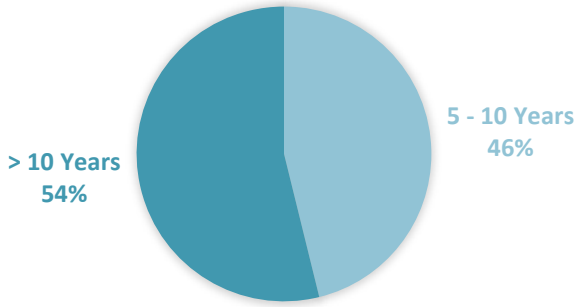

Figure 4.1 Respondent Experience in KSA Construction Industry

The interview questions were divided into three sections. The first section consists of the questions on respondents' background. The second section consists of the questions related to current practices of adopting IBS in the KSA. The third section consists of the questions related to the barriers and enablers in adopting the IBS into the KSA construction industry.

In the interviews, an audio recording was used to capture the responses of the respondents. The interviews ranged from approximately 25 to 30 minutes. Most of the interviews were conducted face to face, however, few were conducted by phone or skype. The audio recording of the interviews was then transcribed. The transcriptions were analyzed using a qualitative analysis software, QSR International NVivo 10, in order to identify common, recurrent, or emergent themes related the current practices, barriers and enablers of the adoption of the industrialized building system.

Online survey questionnaires were conducted in order to verify the interview results in the barriers and enablers of implementing IBS in the KSA construction industry. The population of this survey was also the five (5) main stakeholders of KSA construction industry: project owner, engineering consultant, main contractor, manufacturer and

academician. The response for each barrier and enabler was coded to the numerical options from 1-5 with (1) indicating “strongly disagree,” (2) “disagree,” (3) “neutral,” (4) “agree,” and (5) “strongly agree.”

Thirty-two (32) respondent had responded to the online survey, which are fourteen (14) (44%) were project owners or developers, five (6) (19%) were designers or engineering consultant, nine (9) (28%) were construction contractors, two (2) (6%) were precast manufacturers and one (1) (3%) were academician. The summary of respondents is presented in table 4.2.

Table 4.2 Summary of respondent

	Respondent
Project Owner / Developer	14 (44%)
Design / Engineering Consultant	6 (19%)
Construction Contractor	9 (28%)
Precast Manufacturer	2 (6%)
Academician	1 (3%)

4.2.2 Current Practices of Implementing IBS in KSA Construction Industry

The adoption of IBS is expected to ease to the housing shortage in KSA. This study investigates and assesses the current practices IBS’s techniques in the KSA construction industry, especially in residential housing projects. Interview results reveal that currently, the implementation of IBS is limited to the non-volumetric pre-assembly, which dominantly used in structural concrete elements and building facades. The use of IBS in housing construction projects was founded range from 20% up to 90%, with reducing construction time is the main motivation of adopting the system. The study also found that

residential housing projects with repetitive design and have a substantial number of housing units perceive the benefit of this system. The detail of study finding as follows:

Table 4.3 Current adoption of IBS

No.	Category of standardization and pre-assembly	Sources	
1	non-volumetric pre-assembly	13	100%
2	small-scale sub-assembly categories	12	92%
3	Modular	3	23%
4	Volumetric	1	8%

As per category of standardization and pre-assembly [29], it is found that the current adoption of the industrial building system in the KSA is mostly limited to non-volumetric pre-assembly and small-scale sub-assembly categories. All interviewees (i1-i13) confirmed that they have been adopting IBS's technique for part of their buildings or structures such as wall panels, slabs, precast columns, and beams, as well as small-scale finishing works. Another category that applied only on limited projects is volumetric type of pre-assembly, where one interviewee (i6) has an experience of using that type in a university building project (i.e., Prince Noura university project in Riyadh), for toilet pod. Three (3) other respondents also mentioned it in their interview, although not directly experiencing this technique, that the modular type has been used limitedly in few major projects in several main cities in the KSA. For example, the use of modular components in hotel projects in Makkah and Jeddah (i11), and in housing project for the ministry of interior in Khobar and Jubail (i13).

Table 4.4 Area of construction that applied IBS

No.	Area of construction	Sources	
1	Building facade	13	100%
2	Concrete structure element	12	92%
3	Finishing element	8	62%
4	Pad foundation	6	46%
5	Steel structure element	4	31%

For the non-volumetric type, concrete structural elements and building facades considered as the main applications of IBS in the KSA. Eleven (11) interviewees, who are project owners (i7&i8), engineering consultants (i9&i13), contractors (i1,i5,i6&i11) and manufacturers (i2,i3&i4) have applied it in their project. Interviewee (i8) as the Head of Projects Monitoring and Control Dept. from a project owner stated that: ***'We are using the IBS almost in all area of construction except for earthwork; we have applied precast concrete in a structural element such as a beam, column, and slab.'*-(i8)**. This statement supported by manufacturing interviewee (i2), who said: ***'Normally for housing project we working on, the foundation is prepared with the cast in situ, and after that, the structure element of the building is using the precast, we prepare the load bearing wall, beam and hollow core slab for the structure the element and facade wall as finishing wall.'*(i2)**. The applications of IBS for foundation are mostly used for light structures, such as boundary or perimeter walls, as experienced by five (5) of thirteen (13) interviewees. Interview (i5) as the construction manager from a contractor stated the application IBS for foundation to their project, ***'We are utilizing the IBS to build seven hundred villas or houses; we start with boundary walls of the housing and the externals of the compound. We are using precast for footing pad, column, beam and wall of the boundary wall. For the house itself, we are using precast for facade and stairs.'***. This is also strengthened by interviewee (i3) as the production manager from a precast manufacturer who stated that: ***'For buildings, normally in the foundation, we are using cast in-situ, and for the structural elements such as a column, beam, slab or even load bearing wall as precast and also architectural element likes facade, stairs, and others. For the boundary wall, yes we are using the full precast method, from the foundation, beam, column, and wall.'*** There are also limited

adoption of IBS's technique in pre-engineering steel structure for roof and cladding for high rise buildings, as mentioned by interviewee (i3; i8&i9).

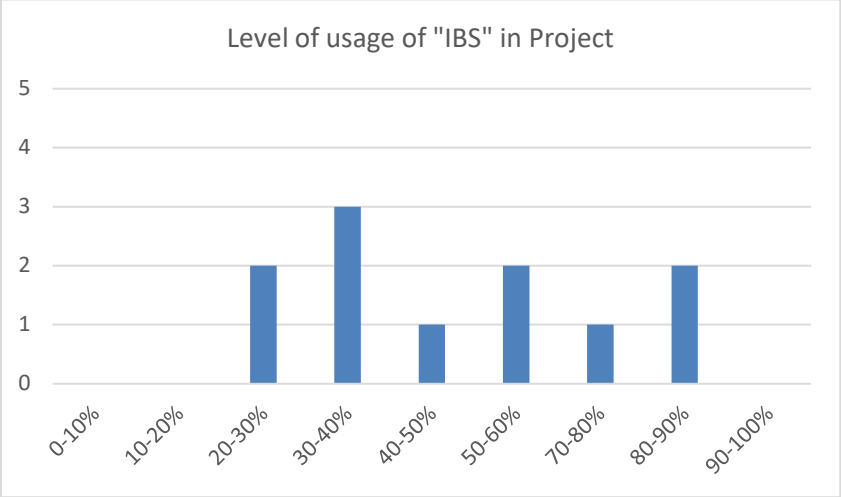

Figure 4.2 Level of usage of IBS in Project

The academicians believe that IBS could be used for 100% of construction works in projects (i12 & i13), as shown in Figure 4.3. However, practically the use of this system are still varies from 20% up to 90%, with the average of 54% of total construction works. The maximum use of IBS to date is in a big housing projects, owned by a state-owned company, which adopted a pre-cast construction method for up to 90% of its construction works. This project scope includes almost seven hundred villas and three hundred apartment units, which is divided into some project packages. The main reason that the owner of this housing project selected to adopt the IBS was that this approach is considered to be the fastest way to deliver its project, as stated by interviewee (i7), ***'IBS, in this case, is precast will ease the construction process, because actually, the company is in a hurry to complete the project. So, IBS is the reason to expedite the project to finish it as soon as possible with required quality of course.'*-(i7)**.

Table 4.5 Motivation in adopting IBS

No.	Motivations for utilizing IBS	Sources	
1	Time	11	85%
2	Quality	6	46%
3	Profit	6	46%
4	Sustainable	3	23%
6	Worker or manpower availability	1	8%

As per shown in table 4.5, reducing construction time, in fact, is the main motivation in adopting the IBS, as agreed by eleven (11) of thirteen (13) interviewees, who are from the practitioner side. The interviewee (i8), who is the head of projects monitoring and control dept. Of a project owner said that: ***'Mainly the motivation for using the IBS is time, to find the fastest way to finish the project.'***. Furthermore, for project owners, the use of IBS also improved quality of works and products. With shorter project completion time, and higher quality of product, project owners not only save project cost but also gain more profit, as per mentioned by interviewee (i10): ***'Firstly the motivation that I can say from the real estate market development for housing complex side they used it for low cost but for better quality. So, the motivation basically they want the high quality of the conventional but at a much lower price so that they can sell it the market.'***. This statement also supported by interviewee (i7) as an owner in Aramco's housing project, which adopted 90% of IBS. Although their project is for they own employees, with reduced time of construction work, they aim for saving cost by adopting IBS, as stated that: ***'if we could finish the project faster, we can bring those people outside to inside and rather than the company paying the outside. By this, we can save the money for the company.'*-(i7)**. Thus, achieving a shorter time of construction works as well as, better quality of works and product, and profitability, become top three main motivations for adopting IBS.

According to the engineering consultants (i9&i13) and academicians (i12), other motivations for adopting IBS are regarding sustainability and environmental factor. They believe that transferring concrete casting from construction sites to factories could eliminate or significantly reduce waste, lessen the impact to the environment, which stated by interviewee (i9) as the managing director from an engineering consultant: ***'For a designer, I would say is the sustainability, that is indirect motivation, but for now, people in this country did not see it yet, but I totally believe if you by using IBS that could save the material, save the environment, not only time and cost but also the efficiency sustainability.'*-(i9)**.

Based on their experience, all interviewees are on the same opinion that housing projects with a significant number of units and have typical or repetitive design are the most appropriate project for adopting IBS. In design perspective, for project effectiveness in adopting IBS, repetitive design is required. As the academician s(I12) supports mentioned that: ***'The use of IBS it would be effective in the project with a repetitive design that needs massive production from the factory.'*** Furthermore, interviewee (I12) argued that creating a building element into pieces and assembled will lead to a beneficial impact to projects because IBS could lead to more precise construction and more accurate compared to the conventional method. To achieve the beneficial impact of adopting IBS in term of cost saving for project owner, from the designer perspective (i13), the minimum number of unit for housing projects should twenty (20) unit. The conventional method would more profitable if the project has the quantity of the housing is less than twenty (20) unit. However the contractor and manufacturer as stated by interviewee (i6&i3), describe the minimum number unit that appropriate for housing project to adopt IBS is more than

hundred units, as interviewee (i6) stated ***'Housing or villa project would be appropriate to use IBS when they have standardized design and not only for two or three house, it has to hundred units of the villa.'*-(i6)**.

Furthermore, the interviewees were also asked about their opinion on future of IBS in the KSA construction industry for next ten years. Most of them (12 of 13) stated that IBS in the KSA construction industry is expected to be successful in the future. The main reasons are it leads to better project performances related to time, cost and quality, which are the KSA construction industry needs to be an alternative to the housing shortage. However, it still needs a consideration about the outlook of economic condition. A couple of interviewees (i3&i4) said that: '***It depends on the economic condition. If the economic condition in KSA is getting better or in good condition, I believe the implementation of precast or IBS could get more space to improve rapidly.'*-(i3)*; 'Precast as one of the techniques in IBS is a very good method for the construction industry, and it is suitable for KSA. Related to the benefits and efficiency compared with cast in-situ, for me I prefer precast method than cast in-situ. Looking to the current condition in the KSA construction, also related the economic condition, if it is going better, I believe precast have a promising future for the next ten years.'*-(i4)**. Moreover, this system is still considered as a new construction method in KSA especially for housing projects. And, one of the interviewees (i12) from the academician argued that this system needs to be settled with the regulation, codes, and guidelines, thus for next ten year he believes there is no a lot of changes in the implementation of IBS. As per he said that:***' For next ten year, I think there is nothing happen, or I can say only a few changes or minimum changing. Because of the shifting process from the conventional to the IBS, it will need time. There are***

***many decisions, regulations, lot of uses, changing and everything. Also, the nature of our culture in beliefs for not changing in a very fast way.'*-(i12)**

4.2.3 Benefits of IBS in KSA Construction Industry

The interview results identified that there are several benefits in implementing IBS in their construction projects. Table 4.5 presents the benefits of adopting IBS. The three (3) main benefit are: improved project performances (Time, Quality and profit); improved productivity which include solving the problem of lack of skilled labors; and improved customer satisfaction. The other benefits include improved safety performance, environment and sustainability, reduced risks, solved design issues, low maintenance cost, and encourage new ideas.

Table 4.6 Interview result in the benefit of adopting IBS

No.	Benefits	Sources	Frequency
1	Improve project performance in term of time delivery, project quality, and increasing company's profit	13 (100%)	54
2	Improve productivity and solve the lack of skilled labor issue	12 (92%)	27
3	Improve ability to gain a higher level of customer satisfaction	11 (85%)	12
4	Improve project safety performance and reduce onsite disruption	9 (69%)	9
5	Environment and sustainability	5 (38%)	8
6	Reduce project risk; solve design issue; low maintenance cost, and encourage to find a new idea	2 (15%)	4

Table 4.7 Respondent distribution on the benefit of adopting IBS

No.	Benefits	Respondent									
		Project Owner (2)		Designer (2)		Contractor (4)		Manufacturer (3)		Academician (2)	
1	Improve project performance in term of time delivery, project quality, and increasing company's profit	2	100%	2	100%	4	100%	3	100%	2	100%
2	Improve productivity	2	100%	2	100%	4	100%	3	100%	1	50%
3	Solve the lack of skilled labor issue	2	100%	2	100%	3	75%	3	100%	2	100%
4	Improve ability to gain a higher level of costumer satisfaction	2	100%	2	100%	3	75%	2	67%	2	100%
5	Improve project safety performance	2	100%	2	100%	2	50%	2	67%	1	50%
6	Reduce onsite disruption	2	100%	2	100%	2	50%	1	33%	2	100%
7	Environment and sustainability		0%	1	50%	2	50%	1	33%	1	50%
8	Reduce project risk	1	50%		0%	1	25%		0%		0%
9	Solve design issue	1	50%		0%	1	25%		0%		0%
10	Encourage to find new idea		0%	1	50%	1	25%		0%		0%
11	Low maintenance cost		0%		0%		0%	2	67%		0%

From the interview, improved project performance regarding time delivery, project quality, and increase companies' profit margin have been seen as the main benefits by all respondents in adopting the IBS. Interviewee (i3) clearly stated that: ***'The major benefits of using this system are absolutely could reduce the time, have a high standard of quality and reduce the total project cost.'*-(i3)**. Furthermore, twelve (12) interviewees mentioned the improvement of project performance in term of increased labor productivity. Adopting IBS into construction projects gives learning curve that lead to increased labor productivity. As experienced by the interviewee (i11), who applied IBS in his project: ***'IBS will make construction easier and also because of the learning curve that will make everything go smoothly with reducing any problems in the execution stage of construction.'*-(i11)**. In the context of the KSA construction industry, adopting the IBS was considered as a way to ease the challenges of the lack of skilled labors. Interviewee (i5) stated that *'**by using IBS, it reduces the need for skilled labor (on construction site) compared to the conventional method. Since here in the KSA it is very difficult to find skilled labor, by using IBS could help for this issue'***.

Most respondents agreed that adopting the IBS helped them improving client satisfaction. However, from the interview results, it is found that clients of housing project could be divided into two. First group is organizations or state-owned companies that provide housing for their employee or housing as university facility (for student or faculty), and housing that provides by the ministry of housing. For this type of housing projects, improved client satisfaction could be easily measured. Interviewee (i13) stated that: ***'For housing project that provides by organizations or the ministry of housing, I believe it could help the ability to gain a higher level of customer satisfaction.'*-(i13)**. The second

category is a public market, where people are the end users of the house that are provided by property developers. For this type of housing projects, it was identified that IBS could not help to gain a higher level of customer, as per explanation from designer (i9&i13) and project owner (i8) that the main reason is most people here in the KSA prefer houses that could easily be modified as per their needs in the future. They do not believe that standardized housed could provide that, because of rigid designs and difficult to be modified. Interviewee (i8) from project owner experienced this issue, which stated that: ***'Currently, the market in housing project, the end user or people who are going to use the house still don't want have a house looks like a Lego house. They want the house that they can modify as per their needs, and some people in Saudi Arabia they do not want have a standardized house.'*-(i8).**

Improving project safety performance, reducing onsite disruption of adjacent operations, and less impact on the environment by reducing waste, also identified as benefits of implementing IBS. These benefits shows that IBS is not only gives a beneficial impact on the technical side but also from the HSE (Health, Safety, and Environment) side, which need to be considered for green or sustainable construction. As mentioned by interviewee (i12) that: ***'the system (IBS) itself will open up for sustainable construction since it is also could reduce the waste of construction material within this system. The waste will consider minimum compared to the conventional construction method or cast-in-place concrete. I consider IBS much cleaner, and then once it arrives in construction site the method of assembly, it will be cleaner, faster and neat compares to the cast-in-place method. So that it will minimize the impact on the environment.'*-(i12)**.

Other benefits that have been identified by some respondents include: reduced project risks, solving unique structural design; encouraging new ideas of design; and low maintenance cost. Regarding design, interviewee (i9) stated that ***'as a design company, IBS opened our eyes, gave us a different way of thinking about the project. Because when you deal with modular or assembly, it puts another constraint to design, so have to be more creative to come up with all issue in the good or beautiful design. Such system will always challenge us, but we always like the challenges to gain more experience'***. As for reducing project risk, interviewee (i7) from project owner group said, ***'if we are using the precast so we are dealing with specialized sub-contractor and have a lot experience before, so they already have identified the risk that could happen during construction in this project.'*** So, this reduces the risk and problem compared to the normal construction method.

4.2.4 Barriers on Implementation IBS in KSA Construction Industry

There are factors that were considered as barriers or challenges in the implementation of IBS in the KSA construction industry, which identified from interview result as shown in table 4.8. Two-thirds (2/3) of the respondent agreed on five (5) dominance barriers, which are considered as the major barriers. They are: lack of awareness or knowledge of IBS; rigid design or design inflexibility in IBS; IBS have less construction error tolerance than conventional construction method; conservative culture with the conventional method; and that adoption of IBS lead to more complex project planning compared to conventional method. Other six barriers include, lack of capability of the manufacturers; logistic issues; owner decisions create restriction in adopting IBS; lack of marketing strategy; lack of regulation and policy, and environmental condition.

Table 4.8 List of barriers of IBS implementation in KSA

No.	Barriers	Sources	References
1	Lack of the awareness or knowledge of the IBS	13 (100%)	20
2	IBS has a rigid design or design inflexibility in the IBS	12 (92%)	18
3	IBS have less construction error tolerance than the conventional method	12 (92%)	12
4	Conservative culture with the conventional method	11 (85%)	13
5	More complex project planning in utilizing IBS compared to the conventional method	10 (77%)	10
6	Lack of the capability of the manufacturer	7 (54%)	9
7	Transportation or delivery and logistic issue	7 (54%)	8
8	Owner's decision restrict to adopt IBS	4 (31%)	7
9	Lack of marketing strategy	2 (15%)	2
10	Lack of regulation and policy from the government	2 (15%)	2
11	Environmental condition	1 (8%)	1

Although IBS has been proven to have beneficial impacts on construction projects, its implementation in the KSA construction industry is still low, especially in residential and housing projects. All respondents agreed that the lack of awareness and knowledge on the IBS is considered the main barriers in adopting such system. As interviewee (i10) said that: ***'the barrier major is the lack of the awareness. It can divide into several types; like the lack of awareness in the general public and also lack awareness of the construction market from real estate development, government stakeholders, including policymaker.'-*** **(i10)**. All interviewees agreed, there were two (2) main reason why the lack of awareness and knowledge was identified as a major barrier that need to be solved. First, this barrier could create other barriers to the implementation of IBS. Interviewee (i9) stated that: ***'From lack of knowledge for sure will bring you to another barrier, such as quality issues and also communication between stakeholders.'-*** **(i9)**. Second, the implementation of IBS as the construction method depends on the main stakeholders which are project owners and designers. Lack of awareness and knowledge of this system, especially to the main stakeholders, will give an huge impact to the adoption of IBS, as mentioned by (i9) from

the designer group, ***'currently the design team, they did not know much about the availability of the system or the benefits of the system, they will not utilize them or use the system in their system.'*-(i9)**. And this statement also supported by interviewee (i7) from the project owner group who stated that: ***'one of the problems is the owners they don't have a very good background, maybe the contractor they already aware about the IBS but the problem is the main stakeholder such as the owner and the consultants.'*-(i7)**.

In term of design, most respondents (12 of 13) also agreed that design inflexibility and less construction error tolerance compared the conventional construction method are also the main challenges in adopting the IBS. As mentioned before on the benefits, this issue was identified for the project that provides housing units in the public market. As mentioned by interviewee (i8) and supported by interviewee (i12): '***it (housing that designed with IBS) is very difficult to change or modified it and people here in Saudi Arabia they want to modify their house in the future like demolish something, add something, that is the culture here. So they want the design of housing that easy to modified.'*-(i12)**. Most interviewees are in a agreement that IBS needs a more flexible design to meet the housing market for public as the end users. However, from the manufacturer side, this barrier could technically be solved, as interviewee (i3) stated that: ***'As per my experience, currently many people still have many wrong understanding about IBS or precast. One of them is, they thought that by using precast their house could not be extended to the future. This is wrong, otherwise by using precast the future modification is easier than the conventional method, we can modify anything. Because it is very easy to modify through the open the joint, there are techniques to modify it.'*-(i3)**.

Other major challenges that are identified by some respondents include: conservative culture with the conventional construction method, more complex project planning, capabilities of manufacturers, and transportation or logistics issues. The conservative culture with the conventional construction method was identified as one of barriers in implementing IBS could be related to the lack of awareness and knowledge in IBS method, as mentioned by interviewee (i12) that: ***'the market here (KSA), there is a customer fear in the IBS or the precast construction method. I know the client here has an afraid of the IBS. I could say it is fell of ignorance; it is more like you do not know what is going on with the new system, so they are more prefer to use the conventional way to construct their building or housing. So, we can call it the fear of changes in the new methods.'-* (i12)**. Furthermore, for project planning stage, there is a perception that IBS leads to more complex project planning compared to the conventional method. However, the designer group (i9&i13) believe it depends on the size of the projects. This barrier was identified for small projects, which typically require a simpler construction method. On the other hand, for big housing projects or mega projects, it is gives more advantages in adopting IBS in their project planning. There are seven (7) of thirteen (13) interviewees who have experience of lack of manufacturer capability and logistic issue in adopting IBS in their project., One interviewee (i8), from the project owner group, has to return to the conventional method from their plan to use IBS because of the manufacturer could not provide the requirement of project, as he said that: ***'I have experienced before in one of my projects that in the planning stage we are thinking to use the precast, so I look to all the manufacturer around Saudi Arabia, and we have difficulties in their capability to provide our project, they need seven months to prepare the precast element of building***

that we need. For me, it is one the challenge even though the precast method has a shorter duration rather than normal construction method in the execution stage, but the manufacturer in here Saudi Arabia also have limitations in their capability of our needs. So, because of this, we are back to the normal construction method.'

Other barriers that were mentioned by the respondents include lack of marketing strategy from manufacturers, environmental condition constraints and lack of policy from the government.

4.2.5 Enablers for IBS Implementation into the KSA Construction Industry

The respondents were also asked on how they overcome the barriers/challenges in adopting the IBS. From the interviews, there were eight (8) factors that could be used to overcome the barriers to the implementation of IBS as listed in table 4.9. The study found two (2) dominant factors that were considered as the main enablers where most respondents (77%-100%) agreed on, they are: training to improve knowledge of stakeholders on IBS and exhibition or campaign to improve the awareness to the people on IBS. Other enablers that were highlighted as important enablers are, having a system or flexible design on IBS project, government's role in enabling IBS in governments housing project, improve the transportation infrastructure, improve the communication system among stakeholders in the early stages of projects, improve the capability of manufacturers, and have a pilot project as a sample IBS project.

Table 4.9 List of enablers of IBS implementation in KSA

No.	Enablers	Sources	References
1	Training and workshop to practitioners in the construction industry to improve their knowledge as well as skills related to IBS	13 (100%)	17
2	Exhibition, seminar and marketing campaign to increase the awareness of construction project stakeholders on IBS	10 (77%)	12
3	Having a system in a precast house that could easily be modified for future expansion without major change with give design options to end user	4 (31%)	6
4	Government's role in enabling the adoption of IBS in governments housing project	4 (31%)	5
5	Improve and maintain the transportation infrastructure including the road conditions	3 (23%)	3
6	Improve communication system among construction project stakeholders from the design stage to the construction stage	2 (15%)	3
7	Improve the capabilities of manufacturers (i.e., Capacity and production process)	1 (8%)	1
8	To have a pilot project as a sample of full implementation of IBS	1 (8%)	1

As lack of awareness was considered the main barriers/challenges, most respondents agreed that two main factors need to be considered as the enablers to overcome those barriers, which are: education and awareness campaign. All interviewees agreed that educating construction project stakeholders on the industrial building system could improve their knowledge as well as skills in adopting this system. This can be done by providing training and workshop to practitioners in the construction industry, including preparing engineers and designers in their university education. As stated by some respondents from the project owner, contractor and academician groups, '***we can utilize the university, use classes and show them this is the future of construction industry'-(i6); 'educating people is the only way to overcome this problem or to increase the implementation of the precast as one of the technique in IBS'-(i8); 'the most important I can say is education. Conduct the training to all the people involved in construction industry.'-(i7);*** Besides education, conducting exhibition, seminar and marketing campaign are identified by most respondents as ways to increase the awareness and

knowledge of construction project stakeholders on the IBS. As stated by some respondents: ***'What should be done for me is the marketing issue. For the precast company if they want other projects to use the IBS or in this case precast they should present themselves more advanced, attractive or professional way'; 'increase the awareness campaign and increase the interaction of the manufacturer, the construction industry, and the people. For example, conduct the exhibition, introduce the IBS start in university bring the product and sample of the IBS project and so on.'***

In term of design, having a system in a precast house that could easily be modified for future expansion without major change is also considered as a major enabler to implement IBS in the KSA. Where mentioned in the barriers of IBS implementation, this can be done, as stated by interviewee (i3) from the manufacturer group, ***'currently, many people still have many wrong understanding about IBS or precast. One of them is, they thought that by using precast their house could not be extended to the future. This is wrong, otherwise by using precast the future modification is easier than the conventional method, we can modify anything. Because it is very easy to modify through the open the joint, there are techniques to modify it. So, gaining the knowledge of the stakeholders is the way to increase the implementation of IBS in the KSA.'*****-(i3)**

The government has an important role in enabling the adoption of IBS. Some respondents indicated that some government projects had adopted precast construction. They believed that as the biggest owner of housing projects, the government could lead the adoption of the IBS into the KSA construction industry. As mentioned by the interviewee (i12) from an academician, besides providing project the role of government in providing regulation,

codes and guideline also needed as per there is still lack of regulation in the implementation of IBS in KSA construction industry.

Other enablers that also mentioned by the respondents include: improving the communication system among the stakeholders in the project from the design stage to the construction stage; improving and maintaining the transportation infrastructure including the road conditions; improving the capabilities of manufacturers; and having a pilot project as a sample of full implementation of the IBS.

4.3 Discussion

4.3.1 Current Practices of IBS in KSA Construction Industry

At the time of this study, IBS as construction method had been implemented in some housing project in the Kingdom of Saudi Arabia. The interview results identified that the adoption of IBS is limited to the non-volumetric and small-scale pre-assembly type of IBS. According to the Gibb & Isack (2003), IBS implementation could be divided into the level as continuum of prefabrication, from the lower material to the complete or fully integrated assemblies (Figure 4.4) [9], [56]. Based on a continuum of prefabrication construction method level, the current implementation of IBS in the KSA construction industry is still in the low level, which is from level 1 up to level 3 as non-volumetric frame building components.

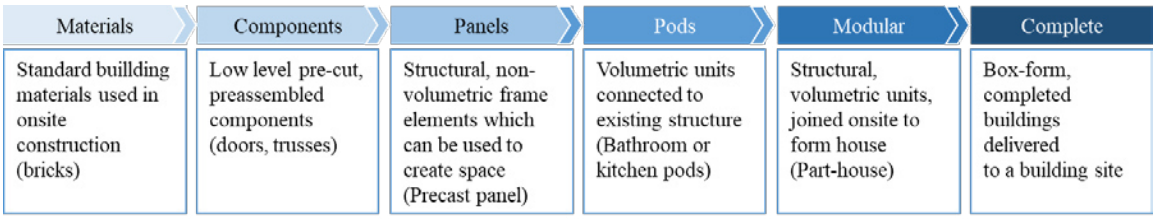

Figure 4.3 Continuum of prefabrication construction methods level [57]

Non-volumetric with precast concrete has been used mostly for concrete structure elements or building components and building facades, which a is in-line with the effectiveness of IBS in a repetitive design nature.

However, the study found that the perception of IBS as off-site construction method with precast in KSA was positive. All participants agreed that IBS technique improved project performances significantly in time, quality and gain a profit to the company. There are also general agreements on that IBS improve the project productivity including solving the lack of skilled labor in the KSA and gain a higher level of customer satisfaction.

4.3.2 Barriers on IBS Implementation in the KSA Construction Industry

The interview results identify several barriers that caused the low level of IBS implementation in the KSA construction industry, especially in housing construction project. Table 4.10 shows the respondent agreement distribution on the identified barriers. Two criteria were used in identifying the main barriers from the interview result, which are the interviewees frequency and the respondents distribution, to find which stakeholders mentioned or experienced those barriers.

Based on interviewee frequency, there are five (5) barriers which are considered as major barriers. Respondents distribution was also need to be considered in identifying the barriers. From the five (5) stakeholders, project owners and designers are considered as the main stakeholders because they have a major role in the adoption of IBS into their projects. Therefore, the barriers that were mentioned or experienced by project owners and designers could be categorized as the barriers that need to be highlighted. The highlighted barriers adding the top five (5) barriers, they are: transportation or logistic issue, lack of the capability of manufacturer and owner's decision restrict to adopt IBS.

Although not listed as major and highlighted barriers, the last three (3) barriers from the interview results cannot be ignored. One of the barriers is related to the government, which is lack of regulation and policy from the government. The interview results identified that the government is one of the biggest project owners in the KSA construction industry. As stated by interviewee (i3), from the manufacturer side, that most of their client is the government project. He said that: ***"KSA construction industry government have a major role. If the government close their project, many companies in the KSA will collapse because the private sector could not provide all the stakeholders of the construction industry."*** **– (i3)**. Furthermore, all barriers from the interview results were verified using an online questionnaire.

Table 4.10 Respondent agreement distribution on barriers of IBS implementation

No.	Barriers	Sources		Respondent									
				Project Owner (2)		Designer (2)		Contractor (4)		Manufacturer (3)		Academician (2)	
1	Lack of the awareness or knowledge on the IBS	13	100%	2	100%	2	100%	4	100%	3	100%	2	100%
2	IBS have a rigid design or design inflexibility in the IBS	12	92%	2	100%	2	100%	3	75%	3	100%	2	100%
3	IBS have less construction error tolerance than conventional method	12	92%	2	100%	2	100%	3	75%	3	100%	2	100%
4	Conservative culture with the conventional method	11	85%	2	100%	2	100%	4	100%	2	67%	1	50%
5	More complex project planning in utilizing IBS compared to conventional method	10	77%	2	100%	2	100%	3	75%	2	67%	1	50%
6	Transportation or delivery and logistic issue	7	54%	1	50%	1	50%	1	25%	2	67%	2	100%
7	Lack of the capability of manufacturer	7	54%	1	50%		0%	3	75%	2	67%	1	50%
8	Owner's decision restrict to adopt IBS	4	31%		0%	1	50%	1	25%		0%	2	100%
9	Lack of marketing strategy	2	15%		0%		0%	1	25%	1	33%		0%
10	Lack of regulation and policy from government	2	15%		0%		0%	1	25%		0%	1	50%
11	Environmental condition	1	8%		0%		0%	1	25%		0%		0%

As shown in table 4.8, the most highlighted barrier is lack of awareness and knowledge about the system. This barrier leads to other barriers that completing the five (5) major barriers of adopting IBS into the KSA, which are: design inflexibility, less construction error tolerance than the conventional construction method, conservative culture with the conventional construction method and more complex project planning. Interviewee (i6) from the contractor side clearly face this major barrier in his project, as he said that:

***'not all people in KSA construction industry have a good knowledge and full experience using this method, I mean yes for specific people they know very well about this system, but the other still don't know about this in detail way. It happens, when owner or designer adopt and deal with the IBS or precast method, they still use the approach of cast in-situ method. What we are facing, there are a lot of changing design, even though the manufacturer already produces the precast panel as per approved specification. So we need to improvise, modify the product as per new specification and this is become a disaster and could not utilize the precast ideally. Based on that experience I summarized the major challenge to implement this system is there is still lack of knowledge in dealing with the IBS or precast.'*-(i6)**

The result of statistical analysis on the barriers and the enabler from the survey questionnaire of IBS implementation in the KSA construction industry verified the interview results. The mean value, median, and mode were used to indicate the respondents' agreement for the barriers and the enablers. As shown in Table 4.11 and Table 4.12:

Table 4.11 Survey questionnaire result of barriers

No	Barriers	MEAN	MEDIAN	MODE
1	The lack of awareness and knowledge on the IBS	3,58	4	4
2	The KSA construction industry conservative culture with the conventional construction method	3,52	4	4
3	Lack of marketing strategy from the manufacturer	3,38	4	4
4	Lack of policy from the government for implementing IBS	3,39	4	4
5	Rigid design or design inflexibility in the IBS, compared to the conventional construction method	3,32	4	4
6	Owner's decision restricts to adopt IBS	3,19	3	3
7	Less construction error tolerance' in the IBS, compared to the conventional construction method	3,06	3	3
8	The lack of capabilities of manufacturers limit the adoption of IBS	2,94	4	4
9	Transportation or logistics issue (i.e., Road condition and access, availability of trucks and driver ability)	2,91	4	4
10	More complex project planning in utilizing IBS compared to project planning using the convention construction method	2,90	4	4
11	Environmental condition	2,43	3	3

It could be concluded from the questionnaire results that all listed barrier from the interviews are considered as the barrier to the implementation of IBS in the KSA.

Mean, median and mode were used to indicate the agreement of the respondents. The value of three (3) indicates “neutral,” and value of four (4) indicates “Agree.” The lack of awareness and knowledge on the IBS has the highest value of the mean, of 3,58 where more than 3,5 which indicates “strongly agree.” The barrier with the lowest value of mean is the environmental condition with 2,43 where close to “disagree,” but the median value and mode of this barrier are three (3) that indicated “neutral.” Thus, still could be considered as a barrier to the implementation of IBS. The questionnaire result of “environmental condition” in line with the interview results where this factor has the lowest frequency. It was mention only by one (1) interviewee from the contractor group.

The research findings on the barriers are in line with the barriers that identified by the previous researchers. According to Kamar et al. (2005), Nasrun et al. (2015) and Mao et al. (2015), Malaysia and China also faced the lack of awareness and knowledge, which was considered as the main barriers. Malaysia and China are considered to have a similar condition with the KSA in term of IBS implementation compared to other developed countries that have adopted the system for decades such as UK, Australia, and Japan. Mostafa et al. (2014) categorized the KSA as a developing country, and indicated that lack of awareness and knowledge as the major barrier to all developing countries along with China, India, Malaysia, Tanzania, Egypt and Nigeria [58].

Barriers in term of design inflexibility which limits design options, that was identified in the KSA, was also faced by developed countries such as USA, UK, Australia, Japan and China where this is considered as the other main barrier [14], [41], [19], [41], [43], [45]. Conservative culture with the conventional construction method and more complex project planning were also identified as the major barriers for a country that relatively new to IBS implementation.

Although they were agreed by less than half of the respondents, two (2) barriers which are transportation or logistic issues and lack of capability of manufacturer also need to be a highlighted. Transportation or logistic issues appear in all discipline of stakeholders and transporting the precast panel from factory to the construction site considered as a critical activity that could impact directly on project performances. Delay of project completion and bad quality could happen when the transportation or logistics issues are not managed. Although lack of capability of the manufacturer does not appear on the designer side; this

barrier comes out from the owner side who has a key role in the adoption of IBS. The level of usage IBS in the project highly dependent on owner decisions.

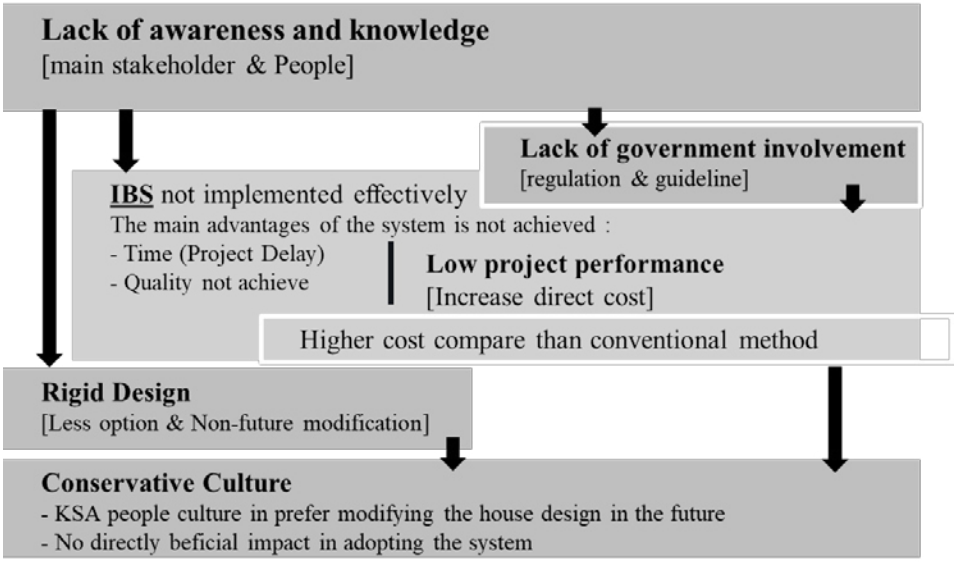

Figure 4.4 Relationship of the identified barriers

The relationship of the barriers from the interview and questionnaire results could be summarized as shown in figure 4.5. Thus, we can conclude that there are four (4) layers of barriers to adopting IBS in the KSA construction industry. The layers as main barriers to the implementation of IBS are shown in figure 4.6.

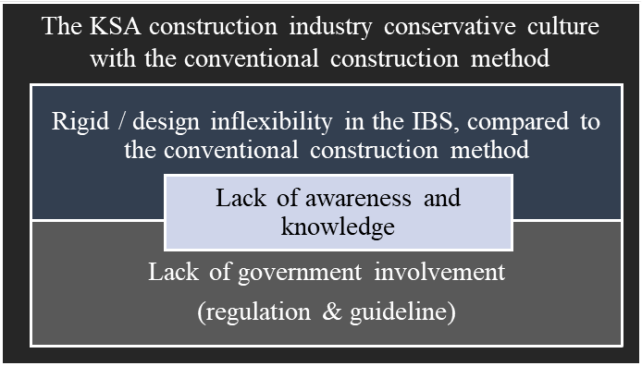

Figure 4.5 Relationship of the identified barriers

4.3.3 Enablers of IBS Implementation in the KSA Construction Industry

Education and increasing the awareness of the stakeholders, in order to know its benefits and technical process of the system were identified to be the main enablers to increase the implementation of IBS in the KSA. Most researchers agree that those two factors are the drivers to increase the implementation of IBS. Twelve (12) of the thirteen (13) respondents stated that education and increasing awareness with exhibition or campaign as their first answer to the question how to overcome the barriers that they found. As interviewee (i13) said that:

***'The first to do is increase the awareness among architect, designer, people and stakeholders related to the business. Also, need to improve the transportation infrastructure, but this is a minor issue, the awareness is the major issue to be solved to increase the implementation of IBS in KSA construction industry.'*-(i13)**

This study found some other enablers that include: flexible design, government's involvement, improving transportation infrastructure, communication and collaboration among main stakeholders, manufacturer capabilities and having a pilot project as a sample in full implementation of IBS. Those findings are in line with the literature review as considered lessons learned from other countries around the world. Even though the enablers are same, but the priority of which factor needs to be focused on is clearly different, as it depends on the current condition of implementation in each country.

Table 4.12 Respondent agreement distribution on enablers of IBS implementation

No.	Enablers	Sources		Respondent									
				Project Owner (2)		Designer (2)		Contractor (4)		Manufacturer (3)		Academician (2)	
1	Training and workshop to practioners in the construction industry to improve their knowledge as well as skills related to IBS	13	100%	2	100%	2	100%	4	100%	3	100%	2	100%
2	Exhibition, seminar and marketing campaign to increase the awareness of construction project stakeholders on IBS	10	77%	1	50%	2	100%	3	75%	2	67%	2	100%
3	Having a system in a precast house that could easily be modified for future expansion without major change with give design options to end user	4	31%	1	50%	1	50%	1	25%	1	33%	0	0%
4	Government's role in enabling the adoption of IBS in governments housing project	4	31%		0%	1	50%		0%	2	67%	1	50%
5	Improve and maintain the transportation infrastructure including the road conditions	3	23%	1	50%	1	50%		0%		0%	1	50%
6	Improve communication system among construction project stakeholders from design stage to the construction stage	2	15%		0%		0%	2	50%		0%		0%
7	To have a pilot project as a sample of full implementation of IBS	1	8%		0%	1	50%		0%		0%		0%
8	Improve the capabilities of manufacturers (i.e. Capacity and production process)	1	8%		0%		0%		0%	1	33%		0%

Table 4.13 Survey questionnaire result of enabler

No	Enablers	MEAN	MEDIAN	MODE
1	Exhibition, seminar and marketing campaign to increase the awareness of construction project stakeholders on IBS	3,90	4	4
2	Training and workshop to practitioners in the construction industry to improve their knowledge as well as skills related to IBS	3,87	4	4
3	Having a system in a precast house that could easily be modified for future expansion without major change with give design options to end user	3,77	4	5
4	Improve the communication system among construction project stakeholders from the design stage to the construction stage	3,73	4	4
5	To have a pilot project as a sample of full implementation of IBS	3,73	4	4
6	Government's role in enabling the adoption of IBS in governments housing project	3,67	4	4
7	Improve and maintain the transportation infrastructure including the road conditions	3,23	4	4
8	Improve the capabilities of manufacturers (i.e., Capacity and production process)	3,23	4	4

Table 4.13 shows the results of survey questionnaire on the enablers in implementing IBS in the KSA construction industry. The listed factors to overcome the barriers for the adoption of IBS indicate the mean value, median, and mode to verify the interview results. The mean values that are greater than the neutral number (3) indicated that the respondents “agree” on the factors as enablers in implementing IBS in the KSA construction industry. The mean values that are supported by median and mode values, as four (4) indicated that the respondents “agree.” Furthermore, based on the mode value of five (5) for having a system in a precast house that could easily be modified for future expansion without major change with giving design options to end user, indicated by most of the respondent “strongly agree” as enablers for the development of IBS in KSA construction industry.

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 Conclusion

This study assessed the current practices of utilizing IBS in the KSA construction industry, especially in residential or housing projects. Industrial Building System (IBS), as an approach to construction, has been implemented in the KSA construction industry. However, its implementation has been limited to the non-volumetric pre-assembly and small-scale sub-assembly categories, which the most application for facades and concrete structural elements. Improved project performance regarding time delivery, project quality, labor productivity and increase companies' profit margin, have been seen as the main benefits, which become the main motivation to implement this system.

Lack of awareness and knowledge on the IBS, design inflexibility, and less construction error tolerance than the conventional construction method are considered the main barriers/ challenges in adopting the IBS into the KSA construction industry. Lack of knowledge on the IBS is linked to other challenges, which include: conservative culture with the conventional construction method and more complex project planning. On the manufacturer's side, lack of capabilities is considered the main barrier, which is identified from their difficulties in meeting project demands.

To improve the adoption of the IBS into the KSA construction industries, education and awareness campaigns are considered the main factors. This enabler is aligned with the main barriers that are faced, which are the lack of awareness and knowledge of this system. Providing training and workshop, as well as exhibition and seminar could be good ways of educating construction project stakeholders on the IBS and its benefits. This includes educating the key stakeholders on having buildings that are developed using this system, which could be modified for future expansion without major change. The government role is also considered important in leading the adoption of the IBS.

5.2 Future Work

The current practices of IBS in KSA construction, including the barriers and enabler factors for developing such system, has been identified and assessed as per research objectives. However, there are some limitations related to the scope and design of this research. This study limits the data collection in qualitative approach using the semi-structured interview to meet research objectives; a quantitative approach is needed for further investigation to assess the main barriers and enabler factor of implementation IBS in KSA.

The results of the study as initial study provide the basis for further studies which will focus on the enabling factors that are considered as the main factors in adopting the industrial building system to the KSA construction industry. A proposed framework for developing IBS for the KSA construction industry consider being a future work with use the result of this study as a basis.

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APPENDICES

1. Appendix 1: Interview Questions

King Fahd University of Petroleum & Minerals Dhahran, Kingdom of Saudi Arabia	**PARTICIPANT INFORMATION FOR KFUPM RESEARCH PROJECT**

Industrialized Building Systems Construction for the Kingdom of Saudi Arabia

The Deanship of Scientific Research (DSR) project No. IN161051.

RESEARCH TEAM

Principal Researcher: Assoc. Prof. Bambang Trigunarsyah Suhariadi, Dept of CEM, KFUPM
Associate Researcher: Prof. Mohammad A. Hassanain, Dept of ARE, KFUPM
A/ Prof. Firas Majed Tuffaha, Dept of CEM, KFUPM
Personnel : Eng. Try Puji Santoso, Dept of CEM, KFUPM

RESEARCH DESCRIPTION

The rapid population growth in Kingdom of Saudi Arabia (KSA) has a massive impact to put pressure on the shortage of housing and existing infrastructure. However, several serious issues currently face the KSA construction industry, such as low productivity of work that has contributed to delay in project completion or postponement; quality of construction services and deliverables; safety on construction sites; and dependency on foreign labor.

Industrialized building system (IBS) can define as the implementation of manufacturing methods to construction-related activities to improve project productivity to meet quality while reducing project cost and duration. IBS starts in a factory as off-site production, which builds a prefabricated or precast component either in modules or units. It continues with to the delivery process from a factory to a construction site, and it ends with the installation of modules or units to complete building construction.

In building or housing project, the IBS is relatively new for KSA construction industry. Research is needed to investigate the IBS implementation for KSA as a solution to improve productivity to meet the demand for the housing shortage.

The research aims to identify and assess the 'industrialization' of a building system in the KSA. The aim will achieve by identifying and assessing: the current practices of utilizing an IBS in the KSA construction industry; the barriers and the enablers for developing an IBS in the KSA.

INTERVIEW QUESTIONS

An instrument for data collection for this study is using interviews with open-ended questions. The semi-structured interview is conducted to collect information about current practices, views, and experiences in the implementation of IBS and to identify the barriers and enablers for developing IBS in the KSA. Thus, the interview result will identify and assess the barriers and enablers to developing IBS by the relevant stakeholders in the KSA construction industry.
Your participation will involve a face-to-face audio-recorded interview at an agreeable location to you and will take approximately 40 minutes of your time. The interview questions divided into three (3) section and will cover:

1. Current practices of utilizing industrialized building system in the KSA construction industry.
2. Barriers and enablers for developing industrialized building system in the KSA
3. How the barriers can be solved or managed.

INTERVIEW QUESTIONS

BACKGROUND INFORMATION:

Section A. Demographic.

1. Could you introduce us your name and your background?
2. How long have you been with the [company name]?
3. Describe your current position in [company name] by your job descriptions generally?
4. How long is your experience in a construction project in Kingdom of Saudi Arabia?
5. What is the standard size of project do you usually work on? (number of people involved, budget, and duration)

MAIN BODY OF INTERVIEW:

Section B. Current practices of Industrialized Building System (IBS).

1. Have you utilized the industrialized building system or off-site construction in any of your previous project recently or past project? And what do you think about it? Information about your experience with industrialized building system of KSA construction industry.
2. In which areas of construction have you used these technologies? (earthwork, structural steelwork, concreting, facade, finishing work, others); could you elaborate on the level of usage (percentages) within this area?
3. What IBS's techniques you have applied in your project? From below categories.

   Standardization and pre-assembly divide into four categories:
   - **small-scale sub-assemblies**, such as door furniture or light fittings.
   - **Non-volumetric pre-assembly**, part of building or structure. For example, wall panels, half slab, precast column and beam, and pipeworks assemblies.
   - **Volumetric pre-assembly**, enclose usable space and installed on-site within an independent structural frame. For example, toilet pods, plant room units, pre-assembled building services risers and modular lift shafts.
   - **Modular building**, the difference is the unit themselves from the building, including enclosing useable space and need to finish by externally on-site with

brickwork or other material. For example, office block and a concrete multi-storey modular unit that used for residential blocks.

4. There are any specific techniques would you like to use more?
5. Do you believe with applied the IBS could help or diminish your ability to gain a higher level of customer satisfaction?
6. Based on your experience, what kind of project or building sectors would be more appropriate for the adoption of IBS?
7. What are the motivations for utilizing IBS in your project?
8. Is there a possibility of using IBS could increase your company's profit margin?
9. Did utilizing IBS increase the project quality? Or increase the predictability of project outcomes?
10. Did adopt the IBS could reduce the project schedule?
11. Did adopt the IBS could improve the project safety performance?
12. Did adopt the IBS could improve labor productivity?
13. Did IBS help solve the lack of skilled labor issue?
14. Did adopt the IBS could reduce onsite disruption of adjacent operations?
15. Did you find any other benefits you have, or your company experienced? Besides the benefit that already mentioned before?

Section C. Barriers / Challenges of Industrialized Building System (IBS).

1. Based on your experience or your company experience, what are the major barriers to implementing IBS's techniques in Saudi Arabia? How do you overcome the barriers?
2. Did you have any experienced specific resistance from (owner or developer, consultant, contractor, manufacturer) that you want to mention?
3. Is conservative culture with the conventional method (cast in situ) in the KSA construction industry one of the challenges in applying IBS?
4. Is the more complex project planning system in IBS is one of the barriers?
5. Is the design inflexibility in IBS is one of the challenges?
6. Do you think IBS have less construction error tolerance than conventional techniques?
7. Did you have any experienced any failure because of the manufacture process delay or lack of quality, or delivery issue?
8. Did you have any experienced resistance from the availability of technology and skilled labor issue?
9. What do you think the future of IBS in the next ten years for KSA construction industry?
10. What should be done to increase the use of IBS in KSA construction industry?

2. Appendix 2: Survey Questionnaire

2.1 English version

King Fahd University of Petroleum & Minerals Dhahran, Kingdom of Saudi Arabia	**SURVEY QUESTIONNAIRE FOR KFUPM RESEARCH PROJECT**

Industrialized Building Systems Construction for the Kingdom of Saudi Arabia

The Deanship of Scientific Research (DSR) project No. IN161051.

RESEARCH TEAM

Principal Researcher: Assoc. Prof. Bambang Trigunarsyah Suhariadi, Dept of CEM, KFUPM
Associate Researcher: Prof. Mohammad A. Hassanain, Dept of ARE, KFUPM
A/ Prof. Firas Majed Tuffaha, Dept of CEM, KFUPM
Personnel : Eng. Try Puji Santoso, Dept of CEM, KFUPM

RESEARCH DESCRIPTION

Industrialized building system (IBS) can be defined as the implementation of manufacturing methods to construction-related activities to improve quality, reduce cost and shorten project duration. It includes: Component manufacture and sub-assembly; Non-volumetric pre-assembly; Volumetric pre-assembly; and Modular building

This research aims to investigate the 'industrialization' of building/construction in the Kingdom of Saudi Arabia

This survey questionnaire is part of the method used to achieve the research aim by identifying the barriers and enablers for implementing IBS. It consists of three (3) section; section 1 consists of several demographic questions, section 2 consists of questions on the barriers, section 3 consists of questions on the enablers of implementing IBS.

This survey will take approximately 10 - 12 minutes of your time.

If you have any questions regarding this survey, please do not hesitate contact:
1. Bambang Trigunarsyah on 013-8608236 or email: bambangts@kfupm.edu.sa
2. Try Puji Santoso on 0530481510 or email: g201538010@kfupm.edu.sa

Thank you for your participation and contribution to this study.

SURVEY QUESTIONNAIRE

Section I. Demographic

6. What is your company's core business?
   a. Project Owner/developer
   b. Design / Engineering Consultant
   c. Construction contractor
   d. Precast Manufacturer
   e. Academician
7. What is your current position _____
8. Number of years within this company
   a. < 5 years
   b. 5 – 10 years
   c. > 10 years
9. Number of years of experience in construction projects in the Kingdom of Saudi Arabia
   a. < 5 years
   b. 5 – 10 years
   c. > 10 years
10. Have you or your company utilized the IBS's techniques (i.e., off-site construction, prefabrication, precast) in your / your company's projects? (Yes / No);
    if yes for _____ years

Section II. Barriers or challenges to implementation of Industrialized Building System (IBS)

Please indicate your agreement with following statements regarding the barriers to / challenges on the implementation of IBS in the KSA construction industry.

		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1.	The lack of awareness and knowledge on the IBS	1	2	3	4	5
2.	Rigid design or design inflexibility in the IBS, compared to the conventional construction method	1	2	3	4	5
3.	Less construction error tolerance' in the IBS, compared to the conventional construction method	1	2	3	4	5
4.	The KSA construction industry conservative culture with the conventional construction method	1	2	3	4	5

		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
5.	The lack of capabilities of manufacturers limit the adoption of IBS	1	2	3	4	5
6.	More complex project planning in utilizing IBS compared to project planning using the convention construction method	1	2	3	4	5
7.	Transportation or logistics issue (i.e., Road condition and access, availability of trucks and driver ability)	1	2	3	4	5
8.	Owner's decision restricts to adopt IBS	1	2	3	4	5
9.	Lack of marketing strategy from the manufacturer	1	2	3	4	5
10.	Environmental condition	1	2	3	4	5
11.	Lack of policy from the government for implementing IBS	1	2	3	4	5
12.	Adopting IBS have a higher initial cost compared to the conventional construction method or cast in-situ	1	2	3	4	5
13.	Negative perception or image in term of unattractive architecture design	1	2	3	4	5

14. Any other benefits or barriers of utilized IBS that were not listed above

_____

Section III. Enablers for the implementation of Industrialized Building System (IBS)

Please indicate your agreement with the following statements regarding the factors to overcome the barriers and enable the implementation of the IBS in KSA construction industry.

		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1.	Training and workshop to practitioners in the construction industry to improve their knowledge as well as skills in adopting the IBS	1	2	3	4	5
2.	Exhibition, seminar and marketing campaign to increase the awareness of construction project stakeholders on the IBS	1	2	3	4	5
3.	Having a system in a precast house that could easily be modified for future expansion without major change in giving a design option to end user	1	2	3	4	5

		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
4.	Government's role in enabling the adoption of IBS in governments housing project	1	2	3	4	5
5.	Improve the communication system among the stakeholders in the project from the design stage to the construction stage	1	2	3	4	5
6.	Improve and maintain the transportation infrastructure including the road conditions	1	2	3	4	5
7.	Improve the capabilities of manufacturers (i.e., Capacity and production process)	1	2	3	4	5
8.	To have a pilot project as a sample of full implementation of the IBS	1	2	3	4	5
9.	To have building regulation and standard guideline on the use of IBS techniques					
10.	To have government involvement, through incentive, to ensure finance and insurance					

11. Other enablers that were not listed above

_____

2.3 Arabic version

استبيان استطلاعي لمشروع أبحاث جامعة الملك فهد	**جامعة الملك فهد للبترول والمعادن** الظهران، المملكة العربية السعودية

بناء أنظمة التشييد الصناعية فى
المملكة العربية السعودية
عمادة البحث العلمى رقم المشروع IN161051

فريق البحث

الباحث الرئيسى : أستاذ مشارك . بامبانج تريجونارسيا سوهاريادى , قسم الادارة و هندسة التشييد, جامعة الملك فهد

الباحث المشارك : أستاذ . محمد أ . حسنين , قسم الهندسة المعمارية , جامعة الملك فهد
: أستاذ مساعد . فراس ماجد تفاحة , قسم الادارة و هندسة التشييد, جامعة الملك فهد

مشاركين أخرين : مهندس . تراى بوجى سانتوسو , قسم الادارة و هندسة التشييد , جامعة الملك فهد

توصيف البحث

يمكن تعريف نظام البناء الصناعي (IBS) بأنه عبارة عن استخدام الطرق الصناعية في الأنشطة المتعلقة بالبناء والتشييد وذلك لرفع الجودة وتقليل التكلفة وتقليص مدة المشاريع. هذه الطرق تشتمل على تصنيع مكونات البناء، تصنيع الأجزاء الفرعية للبناء، التجميع خارج الموقع للمكونات بشكل كامل أو بشكل جزئي. أو النمذجة الكاملة للبناء خارج الموقع

هدف هذا البحث هو التحقق من جدوى أستخدام نظام البناء الصناعي في المملكة العربية السعودية

هذا الإستبيان هو جزء من الطرق المستخدمة في هذا البحث للتعرف على العوائق والممكنات لاستخدام نظام البناء الصناعي. يحتوي البحث على ثلاثة أقسام:
القسم الأول: نبذة عن الشركات أو الأشخاص القائمين بتعبئة الاستبيان
القسم الثاني: يختص بالعوائق أمام استخدام نظام البناء الصناعي
القسم الثالث: يختص بالممكنات والمحفزات لاستخدام النظام

يستغرق هذا الاستطلاع ما يقرب من 10 إلى 12 دقيقة من وقتكم.

<u>إذا كانت لديكم أية أسئلة بخصوص هذا الاستبيان، فيرجى عدم التردد فى الاتصال ب:</u>

1- بامبانغ تريجونارسيا على 8608236 – 013 أو البريد الإلكتروني bambangts@kfupm.edu.sa
2- تراى بوجي سانتوسو على 0530481510 أو البريد الإلكتروني g201538010@kfupm.edu.sa

نشكركم على مشاركتكم ومساهمتكم في هذه الدراسة.

أسئلة الاستبيان

القسم الأول – أسئلة ديموغرافية

1. ما هو مجال شركتك الأساسي:
أ) مالك المشروع / المطور
ب) التصميم / استشاري الهندسة
ج) مقاول البناء
د) مصنع الصب المسبق
ه) مجال اكاديمى

2. ما هو منصبك الحالي _____

3. كم عدد سنوات عملك في هذه الشركة
أ) <5 سنوات
ب) 5 - 10 سنوات
ج)> 10 سنوات

4. كم عدد سنوات الخبرة لديك في مشاريع البناء في المملكة العربية السعودية
أ) <5 سنوات
ب) 5 - 10 سنوات
ج)> 10 سنوات

5. هل استخدمت أنت أو شركتك تقنيات نظم البناء الصناعية (أي البناء خارج الموقع، التصنيع المسبق، او الصب المسبق) في مشاريع شركتك ؟ (نعم لا)؛
إذا كانت الإجابة نعم , فلمدة _____ سنة

القسم الثاني - الحواجز أو التحديات المتعلقة بتنفيذ نظام البناء الصناعي IBS

يرجى الإشارة إلى مدى اتفاقك مع البيانات التالية فيما يتعلق بالحواجز التي تواجه وضع تقنيات نظم البناء و التشييد الصناعية حيز التنفيذ في المملكة العربية السعودية.

		أرفض بشدة	أرفض	محايد	اوافق	أوافق بشدة
1.	قلة المعرفة و الوعي بنظم البناء الصناعية IBS	1	2	3	4	5
2.	جمودية التصاميم أو عدم مرونة التصاميم في نظم البناء الصناعية، بالمقارنة مع طرق البناء التقليدية	1	2	3	4	5
3.	القابلية الأقل للمرونة مع وجود اخطاء فى البناء بتقنية نظم البناء الصناعية، بالمقارنة مع طرق البناء التقليدية	1	2	3	4	5
4.	الثقافة المحافظة لصناعة البناء في المملكة العربية السعودية و المتماشية مع طرق البناء التقليدية	1	2	3	4	5
5.	عدم وجود قدرات لدى الشركات المصنعة يقلل من اعتماد تقنيات نظم البناء الصناعية	1	2	3	4	5
6.	تخطيط المشروع يبدو أكثر تعقيدا ابان استخدام نظم البناء الصناعية مقارنة مع تخطيط المشروع باستخدام طرق البناء التقليدية	1	2	3	4	5

		أرفض بشدة	أرفض	محايد	اوافق	أوافق بشدة
7.	مشكلة النقل أو الخدمات اللوجستية (أي حالة الطرق والوصول إليها، وتوافر الشاحنات و قدرة السائق)	1	2	3	4	5
8.	قرار المالك يقيد اعتماد تقنيات نظم البناء الصناعى	1	2	3	4	5
9.	عدم وجود استراتيجيات للتسويق لدى الشركة المصنعة	1	2	3	4	5
10.	الحالة البيئية	1	2	3	4	5
11.	عدم وجود سياسة من الحكومة لتنفيذ نظم البناء الصناعية	1	2	3	4	5
12.	اعتماد نظم البناء الصناعية لها تكلفة أولية أعلى مقارنة مع طرق البناء التقليدية أو الصب فى الموقع	1	2	3	4	5
13.	التصور السلبي حول كون التصميم المعماري غير جذاب	1	2	3	4	5

14- أي فوائد أو حواجز أخرى خاصة بنظم البناء الصناعية لم تكن مدرجة أعلا

القسم الثالث. العوامل التمكينية لتنفيذ نظام البناء الصناعي IBS

يرجى الإشارة إلى مدى اتفاقك مع البيانات التالية فيما يتعلق بالعوامل الممكنة للتغلب على الحواجز، وتمكين تنفيذ تقنيات نظم البناء الصناعية في مشروعات البناء والتشييد في المملكة العربية السعودية.

		أرفض بشدة	أرفض	محايد	اوافق	أوافق بشدة
1.	توفير التدريب وورش العمل للممارسين في صناعة البناء والتشييد لتحسين المعرفة وكذلك المهارات نحو اعتماد نظم البناء الصناعية.	1	2	3	4	5
2.	اقامة المعارض و الندوات و الحملات التسويقية لزيادة وعي أصحاب المصلحة في اعتماد تقنيات نظم البناء الصناعية.	1	2	3	4	5
3.	وجود نظام في المنزل مسبق التصنيع و الصب و الذي يمكن تعديله بسهولة للتوسع في المستقبل دون تغيير كبير مع إعطاء خيارات التصميم للمستخدم النهائي.	1	2	3	4	5
4.	دور الحكومة في تمكين اعتماد نظم البناء الصناعية في مشروعات الإسكان الحكومي.	1	2	3	4	5
5.	تحسين نظام الاتصالات بين أصحاب المصلحة في المشروع من مرحلة التصميم إلى مرحلة البناء.	1	2	3	4	5

		أرفض بشدة	أرفض	محايد	اوافق	أوافق بشدة
6.	تحسين وصيانة البنية التحتية للنقل بما في ذلك ظروف الطرق.	1	2	3	4	5
7.	تحسين قدرات المصنعين (أي السعة الانتاجية وعمليات الإنتاج).	1	2	3	4	5
8.	توافر مشروع تجريبي كعينة من التنفيذ الكامل لتقنية نظام البناء الصناعى.	1	2	3	4	5
9.	أن تتوافر قوانين تنظيمية خاصة بالبناء والمبادئ التوجيهية القياسية على استخدام تقنيات نظم البناء الصناعى.					
10.	إشراك الحكومة، من خلال الحوافز، لضمان التمويل والتأمين.					

11- العوامل التمكينية الأخري و الغير مدرجة أعلاه

Vitae

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